Patent Claims

1. A catadioptric projection objective for projecting a pattern arranged in an object plane of the projection objective into an image plane of the projection objective with the formation of at least one real intermediate image at an image-side numerical aperture NA > 0.7, having:
an optical axis; and
at least one catadioptric objective part that comprises a concave mirror and a first folding mirror;
wherein a first beam section running from the object plane to the concave mirror and a second beam section running from the concave mirror to the image plane can be generated;
and the first folding mirror is arranged with reference to the concave mirror in such a way that one of the beam sections is folded at the first folding mirror and the other beam section passes the first folding mirror without vignetting, and the first beam section and the second beam section cross one another in a cross-over region.

2. The projection objective as claimed in claim 1, wherein the first folding mirror is arranged such that the first beam section is folded at the first folding mirror and the second beam section passes the first folding mirror without vignetting.

3. The projection objective as claimed in claim 1, wherein the first folding mirror has a reflecting surface facing away from the optical axis.

4. The projection objective as claimed in claim 1, wherein the first folding mirror is arranged such that the first beam section passes the first folding mirror without vignetting and the second beam section is folded at the first folding mirror.

5. The projection objective as claimed in claim 1, wherein the first folding mirror has a reflecting surface facing the optical axis.

6. The projection objective as claimed in claim 1, that has only a single concave mirror.

7. The projection objective as claimed in claim 1, that forms only a single intermediate image.

8. The projection objective as claimed in claim 1, that has at least one second folding mirror in addition to the first folding mirror.

9. The projection objective as claimed in claim 8, wherein the at least one second folding mirror is aligned relative to the first folding mirror such that the object plane and the image plane run parallel to one another.

10. The projection objective as claimed in claim 1, that comprises only a single real intermediate image and a single concave mirror and two folding mirrors that are aligned for a parallel alignment of the object plane and image plane.

11. The projection objective as claimed in claim 1, that has at least one second folding mirror in addition to the first folding mirror, wherein the first folding mirror and the second folding mirror are separate folding mirrors that are mounted in separate mounts.

12. The projection objective as claimed in claim 11, wherein the first folding mirror and the second folding mirror are arranged on opposite sides of the optical axis in such a way thatan effective reflecting surface of the first folding mirror is arranged predominantly or completely on one side of the optical axis and an effective reflecting surface of the second folding

mirror is arranged predominantly or completely on the opposite side of the optical axis.

13. The projection objective as claimed in claim 1, that has a catadioptric objective part that has a concave mirror and a first folding mirror, assigned to the concave mirror, for deflecting the radiation coming from the object plane to the concave mirror,
wherein a second folding mirror is provided for deflecting to the image plane the radiation reflected by the concave mirror, and the second folding mirror is located at least partly in an axial space that is situated in the direction of the optical axis between the object plane and the first folding mirror.

14. The projection objective as claimed in claim 1, wherein the first folding mirror has an inner mirror edge near the optical axis and an intermediate image is arranged in the geometric vicinity of the inner mirror edge.

15. The projection objective as claimed in claim 14, wherein a geometric spacing between the intermediate image and the inner mirror edge is less than 30% of a meridional extent of the intermediate image.

16. The projection objective as claimed in claim 1, wherein the first folding mirror has an inner mirror edge near the optical axis, and an intermediate image is arranged in a geometric space between the inner mirror edge and a field plane geometrically upstream of the first folding mirror and/or an optical component geometrically upstream of the first folding mirror.

17. The projection objective as claimed in claim 16, wherein the field plane is the object plane.

18. The projection objective as claimed in claim 1, wherein at least one intermediate image is arranged in

the optical vicinity of a folding mirror.

19. The projection objective as claimed in claim 1, wherein no optical element is arranged between the intermediate image and an optically most closely situated folding mirror.

20. The projection objective as claimed in claim 1, wherein the intermediate image is arranged at a spacing from an optically closest folding mirror.

21. The projection objective as claimed in claim 1, wherein the projection objective has at least two concave mirrors..

22. The projection objective as claimed in claim 1, wherein the projection objective has at least two catadioptric objective parts which in each case have a concave mirror and a folding mirror, assigned to the concave mirror, for deflecting the radiation coming from the object plane to the concave mirror, or for deflecting to the image plane the radiation reflected by the concave mirror.

23. The projection objective as claimed in claim 1, wherein at least one refractive and/or at least one catadioptric imaging system is placed upstream of a catadioptric objective part that has crossed beam guidance.

24. The projection objective as claimed in claim 1, wherein at least one refractive and/or at least one catadioptric imaging system is placed downstream of a catadioptric objective part that has crossed beam guidance.

25. The projection objective as claimed in claim 1, that comprises a first objective part for projecting the object field into a first real intermediate image,

a second objective part for forming a second real intermediate image with the aid of the radiation coming from the first objective part, a third objective part for forming a third real intermediate image from the radiation coming from the second objective part, and a fourth objective part for projecting the third real intermediate image into the image plane.

26. The projection objective as claimed in claim 25, wherein precisely three intermediate images are provided.

27. The projection objective as claimed in claim 25, wherein two of the objective parts are catadioptric and each have a concave mirror.

28. The projection objective as claimed in claim 25, wherein the first objective part is refractive and the second objective part and the third objective part are designed as catadioptric systems each having a concave mirror and a folding mirror is assigned to each of the concave mirrors in order either to deflect the radiation to the concave mirror, or to deflect the radiation coming from the concave mirror in the direction of a downstream objective part.

29. The projection objective as claimed in claim 1, wherein a number of intermediate images are provided and all the intermediate images are arranged in the geometric vicinity of a folding mirror.

30. The projection objective as claimed in claim 1, wherein a number of intermediate images are provided and all the intermediate images are arranged at a spacing from a folding mirror.

31. The projection objective as claimed in claim 1, wherein a maximum spacing of an intermediate image from a reflecting surface of a folding mirror is less than

10% of the total length of the projection objective.

32. The projection objective as claimed in claim 25, wherein the first objective part is asymmetrically constructed with reference to a plane perpendicular to the optical axis.

33. The projection objective as claimed in claim 25, wherein the first objective part is substantially symmetrically constructed relative to a plane perpendicular to the optical axis.

34. The projection objective as claimed in claim 25, wherein the first objective part has at least two lenses with lens faces that have substantially the same radius.

35. The projection objective as claimed in claim 25, wherein the second objective part and the third objective part are asymmetrically constructed, one of the objective parts being designed predominantly for correcting the image field curvature, and the other objective part being designed predominantly for chromatic correction.

36. The projection objective as claimed in claim 25, wherein the second objective part and the third objective part are substantially symmetrically constructed relative to one another.

37. The projection objective as claimed in claim 1, wherein a first catadioptric objective part has a first optical axis, and a second catadioptric objective part has a second optical axis, and the first and the second optical axes are coaxially arranged.

38. The projection objective as claimed in claim 1, wherein a first catadioptric objective part has a first optical axis, and a second catadioptric objective part

has a second optical axis, and the first and the second optical axes are arranged offset from one another.

39. The projection objective as claimed in claim 1, that has a first and at least one second catadioptric objective part that each have a concave mirror and a folding mirror, assigned to the concave mirror, for deflecting the radiation coming from the object plane to the concave mirror or for deflecting to the image plane the radiation reflected by the concave mirror, there being arranged between the catadioptric objective parts a relay system for projecting into an object plane of the second catadioptric objective part an intermediate image formed with the aid of the first catadioptric objective part.

40. The projection objective as claimed in claim 1, that is designed for ultraviolet light for the wavelength region between approximately 120 nm and approximately 260 nm, in particular for an operating wavelength of approximately 193 nm or approximately 157 nm.

41. The projection objective as claimed in claim 1, that is designed as a dry objective so that during operation a gas-filled gap is present between an exit face of the projection objective and an entrance surface of the substrate.

42. The projection objective as claimed in claim 41, that has an image-side numerical aperture of NA > 0.8 and/or NA ≥ 0.85 and/or NA ≥ 0.9.

43. The projection objective as claimed in claim 1, that is designed as an immersion objective so that during operation an immersion medium with a high refractive index is introduced between an exit face of the projection objective and an entrance surface of the substrate.

44. The projection objective as claimed in claim 43, wherein the immersion medium has a refractive index $n_1 \geq 1.3$ at the operating wavelength.

45. The projection objective as claimed in claim 43, that has an image-side numerical aperture NA > 0.98 in conjunction with the immersion medium.

46. The projection objective as claimed in claim 45, wherein the numerical aperture is NA ≥ 1, and/or NA ≥ 1.1 and/or NA ≥ 1.2 and/or NA ≥ 1.3.

47. The projection objective as claimed in claim 1, wherein a diagonal ratio between a length of a diagonal of a minimum circle centered on the optical axis and enclosing the object field and a length of a diagonal of the object field is less than 1.5.

48. A projection exposure machine for microlithography, having an illuminating system and a catadioptric projection objective for projecting a pattern arranged in an object plane of the projection objective into an image plane of the projection objective with the formation of at least one real intermediate image given an image-side numerical aperture NA > 0.7, having:
an optical axis; and
at least one catadioptric objective part that comprises a concave mirror and a first folding mirror;
wherein a first beam section running from the object plane to the concave mirror and a second beam section running from the concave mirror to the image plane can be generated;
and the first folding mirror is arranged with reference to the concave mirror in such a way that one of the beam sections is folded at the first folding mirror and the other beam section passes the first folding mirror without vignetting, and the first beam section and the

second beam section cross one another in a cross-over region.

49. A projection exposure machine for microlithography, having an illuminating system and a catadioptric projection objective for projecting a mask pattern arranged in an object plane of the projection objective into an image plane of the projection objective with the formation of at least one real intended image,
wherein the projection objective has an optical axis and at least one catadioptric objective part that comprises a concave mirror and a first folding mirror;
wherein a sum S of a number Z of the intermediate images, a number F of the folding mirrors and a number K of the concave mirrors of the projection objective is an odd whole number, and wherein a control device for driving a device for moving the mask and for driving a device for moving the substrate is configured in such a way that the mask and the substrate can be moved synchronously in the same, parallel directions.

50. A method for fabricating semiconductor components and other finely patterned components, having the following steps:
providing a mask having a prescribed pattern in the region of an object plane of a catadioptric projection objective;
illuminating the mask with ultraviolet light of a prescribed wavelength; and
projecting an image of the pattern onto a photosensitive substrate arranged in the region of the image plane of a projection objective with the aid of a catadioptric projection objective in accordance with claim 1.

51. A method for fabricating semiconductor components and other finely patterned units, having the following steps:

providing a mask having a prescribed pattern in the region of an object plane of a catadioptric projection objective;

illuminating the mask with ultraviolet light of a prescribed wavelength; and

projecting an image of the pattern onto a photosensitive substrate arranged in the region of the image plane of the projection objective with the aid of a catadioptric projection objective in accordance with claim 1;

wherein an immersion medium arranged between a last optical face of the projection objective and the substrate is transradiated during the projection.

52. A method for fabricating semiconductor components and other finely patterned units, having the following steps:

providing a mask having a prescribed pattern in the region of an object plane of a catadioptric projection objective;

providing a photosensitive substrate in the region of the image plane of the projective objective;

illuminating the mask with ultraviolet light of a prescribed operating wavelength;

offsetting a finite working distance between an exit face assigned to the projection objective and an entrance surface assigned to the substrate,

wherein the working distance is set within an exposure time interval at least temporarily to a value that is smaller than a maximum extent of an optical near field of the light emerging from the exit face; and

projecting an image of the pattern onto the photosensitive substrate with the aid of a projection objective in accordance with claim 1.

53. The method as claimed in claim 52, wherein at least temporarily a working distance is set that is smaller than four times the operating wavelength, preferably at least temporarily less than 50% of the

operating wavelength, in particular at least temporarily approximately 20% or less of the operating wavelength.